

**IN THE DRAWINGS:**

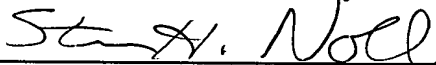
Figure 1 has been amended as shown on the replacement sheet attached hereto.

**REMARKS:**

The present Amendment makes editorial changes in the specification, drawings, claims and Abstract to conform the present PCT application to the requirements of United States patent practice. The cancellation of claims 1-20 in favor of the claims presented herein has been undertaken solely because the amount of strikethroughs and underlining that would have been necessary to confirm original claims to the requirements of 35 U.S.C. §112, second paragraph would have been unduly burdensome and confusing. No change in the claim language has been made for the purpose of distinguishing any claim over the teachings of the prior art of record. Accordingly, no change in the claim language is considered by the Applicant as a surrender of any of the subject matter encompassed within the scope of original claims 1-20.

Early consideration of the application is therefore respectfully requested.

Submitted by,



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**SPECIFICATION****TITLE****"DETECTION OF DIASTOLIC HEART FAILURE"****BACKGROUND OF THE INVENTION**5 **Technical Field****Field of the Invention**

The present invention relates to an implantable medical apparatus for detecting diastolic heart failure, ~~DHF, comprising (DHF), of the type having a~~ DHF determining device for determining at least one blood pressure  
10 parameter for detecting a DHF state of the heart of a patient. The invention also relates to a pacemaker provided with such an apparatus, and a method of detecting DHF, ~~comprising including~~ the step of determining at least one blood pressure parameter for detecting a DHF state of the heart of a patient.

**Background**15 **Description of the Prior Art**

There is a growing recognition that congestive heart failure caused by a predominant abnormality in the diastolic function, i.e. diastolic heart failure, DHF, is both common and causes significant morbidity and mortality. Therefore early detection of DHF is important. Patients do not, however,  
20 seem to have symptoms at an early stage. In addition it has been hard to separate diastolic and systolic heart failure and they may also exist simultaneously.

It has been discovered that among the few parameters, separating diastolic heart failure from systolic heart failure, are certain blood pressure  
25 parameters obtained during work of the patient. Thus ~~US 6 438 408~~ United States Patent No. 6,438,408 describes an implantable medical device for monitoring congestive heart failure, CHF. A plurality number of heart failure parameters indicative of the state of the heart failure are measured employing EGMs, blood pressures including absolute pressures, developed pressures  
30 (= systolic pressures – diastolic pressures) and the time derivative dP/dt, as

well as heart chamber volumes. One of these parameters is the relaxation or contraction time constant  $\tau$  of the heart chamber. This constant  $\tau$  is calculated from a continuous pressure signal and is the drop in ventricular pressure at the end of systole and in the first part of diastole. The  $\tau$  parameter is thus a general parameter reflecting the relaxation process.

#### Disclosure of the Invention

~~This purpose is obtained by an apparatus, a pacemaker and a method of the kind mentioned in the introductory portion of the description and having the characterizing features of claims 1, 10 and 13 respectively.~~

Thus with the present invention the reduced peak and submaximal exercise performance of DHF patients is utilized for detecting DHF. With the technique according to the invention it is possible to detect DHF at an early stage, often before the patient seem to have any symptoms.

In the present invention the workload situation of the patient must be identified, and therefore, ~~according to~~ in an advantageous embodiment of the apparatus according to the invention, an activity sensor is provided for determining the workload of the patient.

~~According to~~ In another advantageous embodiment of the apparatus according to the invention an averaging means unit is provided to form an average value of pulse pressures during a plurality of cardiac cycles with ~~said~~ the workload situation and an average value of pulse pressures measured during a ~~plurality~~ number of cardiac cycles with the patient in rest. In this way the quality of the pulse pressure measurements is improved.

~~According to~~ In other advantageous embodiments of the apparatus according to the invention a wireless communication means unit is connected to ~~said~~ the comparison means unit for automatically sending the results of the comparison of measured pulse pressures with ~~said~~ the reference values to an external receiver ~~means~~, or a ~~storing means~~ memory is provided for storing the results of the comparison of measured pulse pressures with ~~said~~ the reference values. Thus if the pulse pressure has risen above the reference

value in a predetermined way this condition is automatically transmitted to a physician or stored for transmission in connection with a follow-up.

According to ~~still~~ In other advantageous embodiments of the apparatus according to the invention ~~said~~ the pressure measuring means ~~comprise unit~~ includes a pressure sensor adapted for placement in right ventricle or coronary veins of the patient's heart, and ~~said the~~ the pressure measuring means ~~are adapted to determine unit determines the~~ maximum and minimum pressures in a cardiac cycle. It is preferred to place the pressure sensor in the right ventricle or the coronary veins, since the pressures in these places reflect the morphology of the left ventricular or aortic pulse pressure, especially with regard to maximum and minimum pressures.

The invention also relates to a pacemaker provided with the apparatus for detecting DHF and a control means ~~for optimizing that optimizes~~ pacing therapy depending on the result of the comparison of ~~said the~~ the measured pulse pressures with ~~said the~~ the predetermined reference values. The pressure measuring means unit of the apparatus according to the invention then preferably ~~comprises~~ includes a pressure sensor connected to the pacemaker, since it can monitor the pulse pressure of its carrier for long periods. This is an advantage since evolvement of DHF is a slow process.

~~An advantageous~~ In embodiment of the pacemaker according to the invention, ~~comprises~~ a rate responsive sensor ~~for use issued~~ issued as an activity sensor for determining the workload situation of the patient. Even the pressure sensor of the pacemaker can be used as activity sensor.

~~According to~~ In an advantageous embodiment of the method according to the invention, photo-plethysmographic signals are sensed for determining the pulse pressure, since it has been discovered that photo-plethysmographic signals obtained by a sensor placed close to the tissue where a pacemaker or ICD is implanted contain information about pulse pressure.

As mentioned above the measured pulse pressure is compared with a predetermined reference value, and ~~according to~~ in an advantageous embodiment of the apparatus and the method according to the invention ~~said~~

the pulse pressure in a cardiac cycle is measured for a predetermined workload situation and a rest situation of the patient, and the difference between said the pulse pressures measured in said the workload and rest situations is compared with a predetermined reference value for said the difference for DHF detection. A condition of DHF is identified by a higher pulse pressure during workload than a patient with a systolic heart failure would have. The reference value for detection of DHF is preferably obtained from measurements on the patient at an early stage of the implantation period of the apparatus or pacemaker. The patient is supposed assumed not to suffer from DHF at the time of implantation. Therefore, ~~according to~~ in an advantageous embodiment of the method according to the invention, pulse pressures are measured for different workloads of the patient and for the patient in rest at an early time, when the patient is not suffering from DHF, for determining said the reference values. These pulse pressures from an early stage can also be measured for a certain period of time and typical pulse pressures during an identified workload and during rest are gathered and averaged and then stored for later use as reference values for comparison purposes. If later the measured pulse pressure, or average pulse pressure measured during several cardiac cycles, exceeds the reference value determined in this way by a prescribed amount x%, this is used as an indication of DHF.

#### Brief Description of the Drawings

~~To explain the invention in greater detail an embodiment of the invention will now be described with reference to the drawings on which figure 1 is a diagram showing the left ventricular and aortic pressures as a function of time, figure 2 shows a block diagram of an embodiment of a pacemaker according to the invention, figure 3 is a flow chart illustrating the overall collection of pulse pressure data in an embodiment of the apparatus according to the invention, and figure 4 is a flow chart explaining in greater~~

~~detail an example of the procedure for obtaining pulse pressure data according to the present invention.~~

# Description of a Preferred Embodiment

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In the following an embodiment of the invention using a pressure sensor will be described, and by the expression term pulse pressure is ~~meant~~ means the varying pressure in aorta during a cardiac cycle.

10 The above-mentioned pulse pressure can be obtained from the pressure measured in the left ventricle. In figure Figure 1 the top curve shows the left ventricular pressure and the curve below the aortic pressure as a function of time. The magnitude of the pressures are indicated in arbitrary units in ~~the figure~~ Figure 1.

15 The asterisks in the curves of figure Figure 1 denote time points for the maxima and minima of the time derivative of the left ventricular pressure,  $dLVP/dt_{max}$  and  $dLVP/dt_{min}$  respectively. As the aortic valves open close to the point  $dLVP/dt_{max}$ , the aortic pressure is close to the left ventricular pressure at this point of time.

20 During the period from  $dLVP/dt_{max}$  to  $dLVP/dt_{min}$  blood flows into aorta. The maximum of aortic pressure is situated in this period. The pulse pressure ~~can~~ consequently can be obtained from the left ventricular pressure by subtracting the pressure at the point of  $dLVP/dt_{max}$  from the maximum of the left ventricular pressure obtained during the mentioned period.

25 If the conditions are such that pressure signals from other parts of the hemodynamic system are morphologically similar to the left ventricular pressure, these signals can also be used for determining the pulse pressure in the present invention, since only relative changes have to be determined for detecting DHF.

30 Figure 2 shows an embodiment of a pacemaker according to the invention comprising basic pacemaker circuits 20. A pressure sensor 2 is

located in the right ventricle 18 of a patient's heart and connected to the pacemaker 4. The signals from the pressure sensor 2 are supplied to an A/D-converter 10. After A/D-conversion the time derivative of the signal is formed in a derivation unit 16. The time derivative of the pressure signals are filtered  
 5 in the low pass filter 12 before supply to the microprocessor and supporting circuits 14. Since time derivation promotes high frequency noise, it is advisable to eliminate in this way possible false peaks and valleys, which could be interpreted as  $dLVP/dt_{max}$  and  $dLVP/dt_{min}$ . The filtered signals are supplied regularly into a microprocessor and supporting circuits 14.

10 Located in the pacemaker 4 is an activity sensor 6 ~~which~~ that is connected to an activity measuring unit 8 for determining the workload of the patient. A corresponding activity or workload signal is fed to the microprocessor and supporting circuits 14.

Figure 3 is a flow chart illustrating an example of the overall process for  
 15 collecting pulse pressure data. The development of DHF is a slow process as mentioned. A timer, at 26 in ~~figure~~ Figure 3, is therefore provided for activating pulse pressure measurements on a regular basis for reducing the current drain and releasing microprocessor power.

Collection of pulse pressure data is performed for different workloads  
 20 of the patient, at 22 in ~~figure~~ Figure 3. As mentioned above the collection process is activated by a timer, at 26, and therefore the process has to wait for activation by the timer before starting, at 24. As the process is started, at 28, pulse pressure data are stored in different intermediate memory locations depending on the workload of the patient, at 30. Addresses to this memory  
 25 locations are obtained from a table pointed to by the workload or activity measuring unit depending on the workload or activity,[[.]] at 32. Pulse pressure data from the intermediate memory is then stored in another memory according to the address obtained in the preceding step for later analysis, at 34 .

30 To improve the accuracy of the data stored the procedure of storing pulse pressure data can be performed by forming a floating mean value. One way to do this is to add a fraction  $1/k$  of a new pulse pressure value  $P(i)$  to the



pulse pressure value stored  $P_{\text{stored}}$  at the memory location pointed to by the activity measuring unit and form a mean value  $P_{\text{store}}$  according to the following equation

$$P_{\text{store}} = \frac{P(i) + P_{\text{stored}} \times (k - 1)}{k}$$

5 Figure 4 is a flow chart illustrating in greater detail the procedure for obtaining the pulse pressure.  $P_{\text{max}}$  and  $P_{\text{min}}$  denote temporary storages of maximum and minimum aortic pressures.

In order to start the pulse pressure measurements a QRS has to be detected , at 38 in figure Figure 4, after reset of  $P_{\text{max}}$  and  $P_{\text{min}}$ , at 36.

10 Pressure samples  $P(i)$  are then stored continuously together with the time derivative  $dP(i)/dt$  for comparison, at 40. A certain number of contiguous samples have to exist simultaneously, so that the above-mentioned filtering of the time derivative of the pressure is in accordance with the length of the filter coefficients. Care must be taken so that the delay in the filter influences the  
15 selection of corresponding pressure samples in a timely fashion, i.e. the pressure samples are picked selected with the same delay.

When  $dP/dt_{\text{max}}$  has been found, at 42 and 44, the pressure at that point in time is selected as the minimum pressure  $P_{\text{min}}$ . The pressure then rises in the aorta and the maximum pressure during systole occurs in the period  
20 between  $dP/dt_{\text{max}}$  and  $dP/dt_{\text{min}}$ , cf. the description of figure Figure 1. In the process illustrated in figure Figure 4 a simplified approach is used for determining maximum pressure  $P_{\text{max}}$ . Instead of determining the point of time for  $dP/dt_{\text{min}}$  a timer is started at the point of  $dP/dt_{\text{max}}$ , at 46 in figure Figure 4 and  $P_{\text{max}}$  is determined according to steps 48, 50, 52, 54 till timer overflow, at  
25 56. Such a timer procedure is justified since the systolic time period in practice varies little. The pulse pressure is then obtained by subtracting  $P_{\text{min}}$  from  $P_{\text{max}}$ , at 58, which is the output of the process.

Instead of determining the pulse pressure with ~~the aid of~~ pressure sensors, it can be determined by photo-plethysmography. Photo-  
30 plethysmographic signals from a sensor placed close to the tissue at the

location of the implanted pacemaker or ICD contains information on pulse pressure. Thus such photo-pletysmographic signals can be used as an alternative for determining the pulse pressure.

5 Although modifications and changes may be suggested by those skilled in the art, it is the invention of the inventors to embody within the patent warranted heron all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

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